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TACTICAL SIMULATION USING A REAL ENVIRONMENT.(U)
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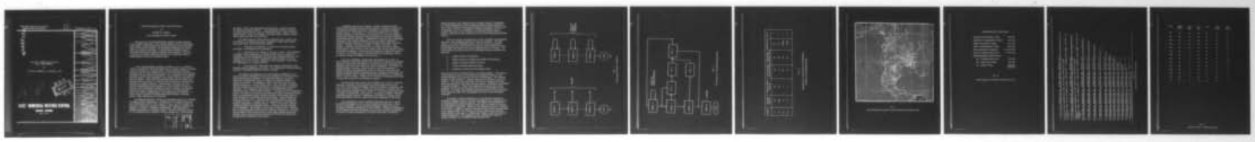

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TECHNICAL NOTE 76-3

TACTICAL SIMULATION USING A
REAL ENVIRONMENT

BY

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See Form 1473

FLEET NUMERICAL WEATHER CENTRAL

MONTEREY, CALIFORNIA

MAY 1975

Tactical Simulation Using a Real Environment

by

Kenneth W. Ruggles

Fleet Numerical Weather Central

The success of an environmentally sensitive mission depends on the complex interaction of the tactical options and the environment. Assessments of environmental impact should provide for the full interaction of the mission phasing and conditional probability associated with real weather occurrences. A general time-dependent model is discussed which tests a tactical mission profile against a data base of 28 years of actual weather occurrences and summarizes environmental effects in terms of mission success.

In any environmentally-sensitive operation, be it a commercial venture as drilling for oil in the North Sea or a military venture as landing a force of Marines on a hostile beach, a significant factor directly affecting cost and often affecting success is the interplay of the mission execution and the imposed environment. The complexity of the interplay directly depends on the complexity of the mission and its sensitivity to the environment. While this statement presents itself as obvious and perhaps trivial once said, it often has been ignored in the planning and execution of complex missions. Traditionally, planners have used simple probabilities for the occurrence of critical weather events as a measure of the probability of mission success or failure. In instances where the mission outcome and mission costs are not significantly altered by weather considerations, such approaches are adequate. In cases where the penalty for unexpected weather factors is mission failure, better approaches are necessary.

An alternate approach, and the one presented herein, is to simulate a complex mission operating in a background of real weather events as they historically occurred over a period of years, and then express the result as a measure of success or failure. This approach considers the influence of phasing, conditional probabilities, and interactions of multiple parameters in a realistic fashion. The basic question we pose is, "If a mission were to start on a given calendar day, at the location

specified, what is the probability it will succeed, and how long will the mission execution require?" The hypothesis is there is some day or period of days which is more favorable than others. This is reasonable to expect, since, for example, one would prefer building a house during those days which are rain free.

Our model approach starts with the statement that a mission can be defined as an ordered set of time-sequenced events called phases. Each phase must meet the following criteria:

a. Each phase is defined by a single set of limiting weather parameters, including forecast parameters.

b. Each phase has a duration of 6 hours or more. This limitation is dictated by the coarseness of weather history used to compute the simulation, and the fundamental time step of the computer program. The weather history used by Fleet Numerical Weather Central has a basic granularity of 12 or 24 hours, depending on the parameter. These data are interpolated at a 6-hourly interval.

c. For each phase, there must be a defined consequence if the limiting weather condition is exceeded. The consequence is either mission failure or a specified alternative course of action.

The implied consequence of successful phase completion for all phases except an alternative phase is the beginning of the next phase in order until mission completion. An alternative phase is one which represents an alternative course of action if the limiting criteria of a phase are exceeded. An alternative action phase must meet the same criteria imposed on a normal mission phase, with the added constraints that the consequence of successful phase completion must be uniquely specified. The exception to this criteria is that alternative which effectively says, "wait for better weather." Through the use of alternative phases, the analyst can specify any reasonable number of courses of action based on successively worse weather conditions and simulate delays or costs incurred due to weather-associated damage. Some examples are shown in figures 1 and 2. Note the basic mission sequence executes each phase in order. In figure 1(a), the consequence of exceeding the weather constraints is a mission delay. Figure 2 shows how, through combining normal and alternative phases, a complex mission structure can be simulated. Both figures 1 and 2 depict a mission end. The fact that a mission reaches an end does not imply the mission was a success. The execution of each phase results in time being charged against the mission, and it may be the time accrued at the end of the mission may exceed that time allowed for the mission.

In general, one does not initiate a weather-sensitive mission without prior knowledge of the expected weather. Prudence dictates use of weather forecasting skill prior to initiating a particularly sensitive weather phase. For example, if a phase of the mission is to conduct diving operations in the vicinity of an offshore reef, some care might be exercised in having assurance of both favorable sea and tide conditions before beginning the operation. Exploitation of forecast skill is presently simulated in the model by allowing the user to require a forecast of favorable weather conditions for some specified period before the phase begins. Presently, the model assumes a "perfect" forecast. This requires we limit the forecast period to one where the forecast skill is for all intents "near perfect" in the context of the mission and the weather parameters of interest. A better approach might be to allow the forecast to vary over the known range of forecast skill before beginning a phase, by adding a random variability to the forecast.

As in any simulation, proper input specification is crucial. In those instances where this analysis has been run in support of operational planning, proper phase definition has been the most time consuming and difficult of all those tasks needed to run the simulation. The process of orderly defining a mission, phase by phase, and the assignment of threshhold values and alternative courses of action to each phase will quickly establish whether the planned course of action is reasonable, and almost invariably leads to further insight into weaknesses in and alternatives to a plan of action. Figure 3 is an example of a planning sheet used to define the mission for the simulation program.

The basic data base used by the simulation is a 28-year continuous sequence of weather events maintained in digital field format by the U.S. Navy Fleet Numerical Weather Central at Monterey, California. The basic data set is ordered on a 63x63 grid referenced to a Northern Hemisphere polar stereographic chart. (Figure 4) Distance between grid points is roughly 500 kilometers, and varies as a function of latitude. Standard parameters include pressure, temperature, and winds for various levels of the atmosphere; and sea, swell, and current definition for the ocean.

Some parameters, such as satellite-observed cloud cover, could be input to the model but cover a much shorter historical span. Others, such as precipitation, can be input from historical weather records or computed by models operating on the basic fields. While basic parameters can be handled with ease and little cost, the cost of running simulations on derived or special parameters can become quite high, in that they

require creation of the historical data set before running a simulation. For marine applications, Fleet Numerical Weather Central maintains a set of over 40 million historical observations of weather over the oceans of the world, plus has a capability of running diagnostic models to compute fine-scale ocean currents and secondary weather effects. Figure 5 tabulates the basic working data set at Fleet Numerical Weather Central.

Given the mission specifications and the supporting environmental data base, the simulation program is run in two sections. The first section, or actual simulation section, runs the mission against the historical data base, successively assuming a new starting date over a period which can extend to up to six months for each of 28 years. For each starting date and each year, the simulation program computes and presents:

a. length of time to run mission

b. length of time to complete each phase of the mission

c. number of mission failures by phase

d. cause of mission failure by phase

e. sequence of events for each mission start.

The second part of a simulation run is a summary program. The purpose of the summary program is to consider the aggregate results of each mission started on the same day over the 28-year period. The summary program is still evolving. A sample output for one mission is shown in figure 6. For each Julian start date, the data are summarized for the entire mission and for each phase of the mission. Statistics are presented as shown in figure 7. Based on simulation runs made to date, these statistics are not always the most useful or even meaningful for some missions. Presently, the summary program is revised for each simulation run to produce results most meaningful to the users of the simulation technique.

In summary, mission simulation in a real weather environment provides a realistic basis for assessing feasibility and assigning risk to an environmentally sensitive mission. The output of the simulation is the expectation for mission failure and the time to complete the mission as a function of start date. Implicit in the definition of time to complete is the cost to complete. There is some time beyond which mission failure is the logical result. The occurrence of times greater than this time, taken with the occurrence of a catastrophic failure, define the expected mission failure rate. The aggregate result, intelligently applied to mission planning, is a powerful weather support tool.

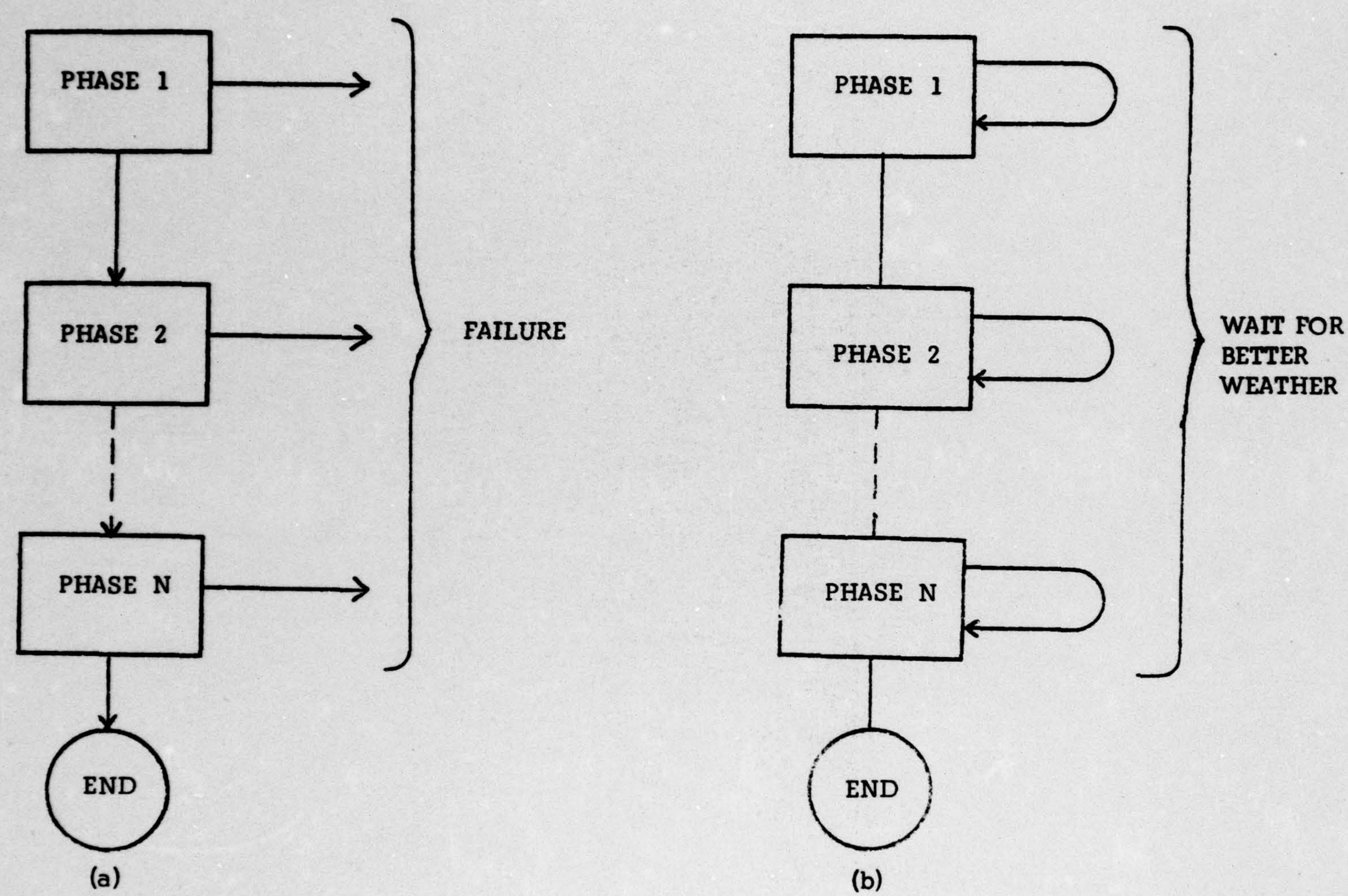

Fig. 1

Some Simple Mission Profiles

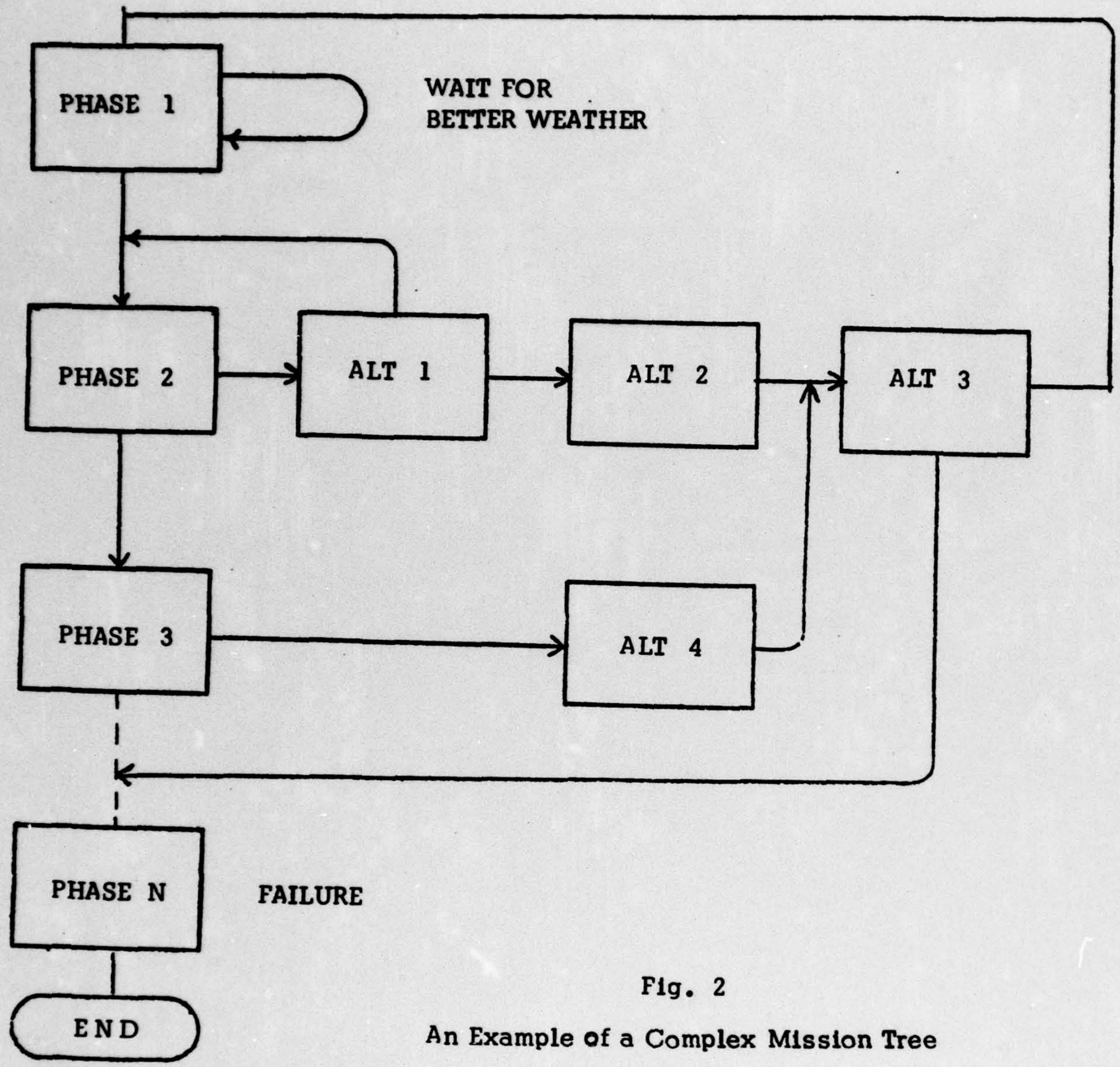

Fig. 2

An Example of a Complex Mission Tree

Phase	Duration (hours)	Forecast period (hours)	Wave height constraint (ft)	Wind speed constraint (kts)	Alternative	Go to
1	24	24	12	25	A1	--
2	120	36	6	10	A2	--
A1	6	--	20	50	None	1
A2	6	--	12	25	None	2

Fig. 3

Example of a Mission Plan for Offloading Cargo Over an Exposed Beach.

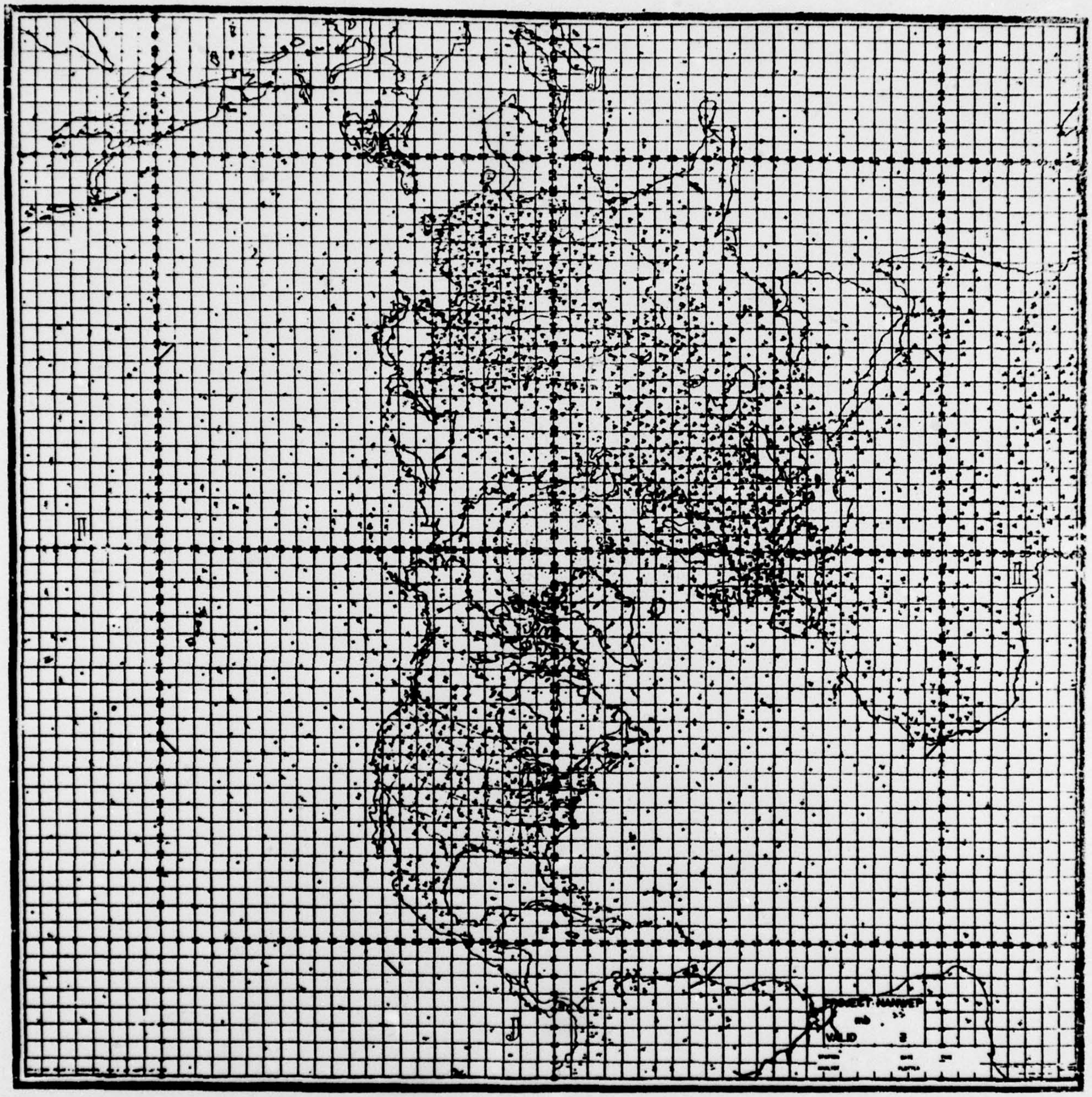

Fig. 4

Fleet Numerical Weather Central Northern Hemisphere Grid

FLENUMWEACEN DATA BASE

Historical Atmospheric Fields		288,000
Historical Oceanographic Fields		112,000
FNWC Atmospheric Fields		671,000
FNWC Oceanographic Fields		385,000
Ship Synoptic Observations		43,000,000
Naval Air Station Hourly Obs		3,750,000
Bathythermograph Observations		
(a)	Digitized XBT traces	214,000
(b)	Mechanical Bathy	105,000
(c)	Station Casts	620,000
		939,000

Fig. 5

Fleet Numerical Weather Central Data Base

```
FOR START DATE:140  MISSION TIME: 144.  ELAPSED TIME: 636   FOR DAYS:  26.5
1111FFFFFFFFFFFFFFFFFFFFFFFFFFFFFFFFFFFFFFFFFFFFFFFFFFFFF22222222HHHHHHHHH22HHHHHHHHHHHHHHHHHHHH3333333333

FLAGGED HOLD POINTS (HHAAOPP)HH:HX TYPE, AA:AMT OVER, PP:PHASE OF MISSION
  100002
CORRESPONDING TIMES (XTTTT) X:0 NORMAL FAILURE. 7:HOLD FAILURE. 9:FORECAST HOLD FAILURE. TTTT:TIME. HRS
  93036

FOR START DATE:141  MISSION TIME: 144.  ELAPSED TIME: 612   FOR DAYS:  25.5
1111FFFFFFFFFFFFFFFFFFFFFFFFFFFFFFFFFFFFFFFFFFFFFFFFFF22222222HHHHHHHHH22HHHHHHHHHHHHHHHHHHHH3333333333

FLAGGED HOLD POINTS (HHAAOPP)HH:HX TYPE, AA:AMT OVER, PP:PHASE OF MISSION
  100002
CORRESPONDING TIMES (XTTTT) X:0 NORMAL FAILURE. 7:HOLD FAILURE. 9:FORECAST HOLD FAILURE. TTTT:TIME. HRS
  93036

FOR START DATE:142  MISSION TIME: 144   ELAPSED TIME: 588   FOR DAYS:  24.5
1111FFFFFFFFFFFFFFFFFFFFFFFFFFFFFFFFFFFFFFFFFFFFFF22222222HHHHHHHHH22HHHHHHHHHHHHHHHHHHHH3333333333

FOR START DATE:143  MISSION TIME: 144.  ELAPSED TIME: 564.  FOR DAYS:  23.5
1111FFFFFFFFFFFFFFFFFFFFFFFFFFFFFFFFFFFFFFFFFF22222222HHHHHHHHH22HHHHHHHHHHHHHHHHHHHH3333333333

FOR START DATE:144  MISSION TIME: 144.  ELAPSED TIME: 540   FOR DAYS:  22.5
1111FFFFFFFFFFFFFFFFFFFFFFFFFFFFFFFFFFFFFFFFFF22222222HHHHHHHHH22HHHHHHHHHHHHHHHHHHHH3333333333

FOR START DATE:145  MISSION TIME: 144   ELAPSED TIME: 516   FOR DAYS:  21.5
1111FFFFFFFFFFFFFFFFFFFFFFFFFFFFFFFFFFFFFF22222222HHHHHHHHH22HHHHHHHHHHHHHHHHHHHH3333333333

FOR START DATE:146  MISSION TIME: 144   ELAPSED TIME: 492   FOR DAYS:  20.5
1111FFFFFFFFFFFFFFFFFFFFFFFFFFFFFFFFF22222222HHHHHHHHH22HHHHHHHHHHHHHHHHHHHH3333333333

FOR START DATE:147  MISSION TIME: 144.  ELAPSED TIME: 468   FOR DAYS:  19.5
1111FFFFFFFFFFFFFFFFFFFFFFFFFFFFF22222222HHHHHHHHH22HHHHHHHHHHHHHHHHHHHH3333333333

FOR START DATE:148  MISSION TIME: 144.  ELAPSED TIME: 444   FOR DAYS:  18.5
1111FFFFFFFFFFFFFFFFFFFFFFFFF22222222HHHHHHHHH22HHHHHHHHHHHHHHHHHHHH3333333333

FOR START DATE:149  MISSION TIME: 144   ELAPSED TIME: 420   FOR DAYS:  17.5
1111FFFFFFFFFFFFFFFFFFFFF22222222HHHHHHHHH22HHHHHHHHHHHHHHHHHHHH3333333333

FOR START DATE:150  MISSION TIME: 144   ELAPSED TIME: 396   FOR DAYS:  16.5
1111FFFFFFFFFFFFFFFFF22222222HHHHHHHHH22HHHHHHHHHHHHHHHHHHHH3333333333

FOR START DATE:151  MISSION TIME: 144   ELAPSED TIME: 372   FOR DAYS:  15.5
1111FFFFFFFFFFFFF22222222HHHHHHHHH22HHHHHHHHHHHHHHHHHHHH3333333333

FOR START DATE:152  MISSION TIME: 144   ELAPSED TIME: 348   FOR DAYS:  14.5
1111FFFFFFFFF22222222HHHHHHHHH22HHHHHHHHHHHHHHHHHHHH3333333333
```

Fig. 6
Sample output for each mission

DAY	WORST CASE	BEST CASE	AVE. CASE	DEV.	CASES 15 DA.	OVER 30 DA.
98	60	10	26	15	22	10
99	59	10	28	15	20	10
100	58	10	28	15	20	11
101	57	10	28	15	19	12
102	56	10	27	14	20	12
103	55	9	27	14	20	12
104	54	8	26	14	22	11
105	61	8	26	14	22	10
106	60	8	25	14	20	10
107	59	8	24	14	17	9
108	60	7	25	15	16	9
109	83	6	25	17	17	8
110	82	7	24	17	18	7
111	81	8	24	16	19	7

Fig. 7

Sample output of Summary Program

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